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Report to Congressional Requesters

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CLIMATE CHANGE

Information on Limitations and Assumptions of DOE's Five-Lab Study



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**Resources, Community, and
Economic Development Division**

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September 8, 1998

The Honorable Larry Craig
The Honorable Chuck Hagel
The Honorable Jesse Helms
The Honorable Frank Murkowski
United States Senate

Human activities, primarily those related to energy production and use, are increasing the concentrations of carbon dioxide and other "greenhouse gases" in the atmosphere. These heat-trapping gases are believed to contribute to global warming, which could lead to future climatic changes. To address the potential consequences of climate change, the United States and other countries have entered into international negotiations and agreements. In October 1997, the administration proposed stabilizing U.S. emissions of greenhouse gases at 1990 levels by no later than 2012. The most recent agreement, known as the Kyoto Protocol, was negotiated in December 1997 in Kyoto, Japan, and calls for even greater reductions in U.S. greenhouse gases.¹ Of the six greenhouse gases covered by the Kyoto Protocol, carbon dioxide is of significant concern for the United States, constituting more than 80 percent of U.S. greenhouse gas emissions in 1996.

Prior to the Kyoto conference, a September 1997 Department of Energy (DOE) study² by five DOE national laboratories quantified the potential for energy-efficient and low-carbon³ technologies to reduce U.S. carbon emissions⁴ to 1990 levels by 2010. Among other things, the study (also known as the five-lab study) concluded that an aggressive national commitment to energy-efficient and low-carbon technologies—coupled with an increase in the price of carbon-based fuels of \$50 per metric ton⁵

¹The Kyoto Protocol to the United Nations Framework Convention on Climate Change would require the United States to reduce its anthropogenic, or man-made, carbon dioxide equivalent emissions during the period from 2008 to 2012 to 7 percent below 1990 levels; however, this protocol has not yet been ratified by the U.S. Senate.

²Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies (Sept. 22, 1997).

³Low-carbon technologies can reduce carbon emissions by employing a less carbon-intensive fuel, such as switching from coal to natural gas.

⁴In the laboratories' study, carbon dioxide is measured in units of carbon, defined as the weight of the carbon content of the carbon dioxide molecule (carbon constitutes 12/44 of the molecule).

⁵A metric ton is 1,000 kilograms, or about 2,200 pounds.

—could reduce carbon emissions to the levels they were in 1990, with energy savings estimated to roughly equal or exceed costs. In view of the study's potential influence on U.S. climate change policy, as requested, we are providing you with information on (1) how the study's scope and methodology may limit its usefulness, (2) key assumptions that may have influenced the study's results, and (3) the study's role in the formulation of the October 1997 climate change proposal and the Kyoto Conference's emission-reduction goals for the United States.

Results in Brief

The five-lab study is an important step in evaluating the role that energy-efficient and low-carbon technologies can play in the nation's efforts to reduce global warming gases. However, the study's usefulness is limited because it does not discuss the specific policies needed to achieve its estimate of 394 million metric tons of carbon reductions by 2010 and does not fully consider the costs to the nation's economy of reaching this goal. For example, a policy involving tax credits as an incentive for consumers to make energy-efficient purchases could have different economic and budgetary impacts from a policy requiring manufacturers to meet minimum energy-efficiency levels for products. According to DOE laboratory officials, specifying the types of policies needed to achieve such significant reductions by 2010 was not one of the study's objectives. Furthermore, the study assumes a fee of \$50 per ton for carbon emissions, which would increase the cost of energy; however, the study does not evaluate the broader impacts that this cost may have on the economy. DOE laboratory officials acknowledge that the study does not examine the broader economic impacts of such a carbon fee on the U.S. economy but said that, in their opinion, these broader economic impacts would be minor.

The study's finding that the widespread adoption of energy-efficient technologies can be achieved with low to no net cost to the nation is heavily dependent on the assumptions made for four sectors of the U.S. economy—buildings, industry, transportation, and electricity production. Among the groups that we interviewed, we found a disparity of views on key assumptions that may have influenced the study's results. Several of the groups⁶ questioned some of these assumptions as being too optimistic, such as those about the payback period, rate of adoption of new technologies, or timing of technological breakthroughs. For example, the study assumes that industry will change the length of time expected for a capital investment to recover its costs—known as the payback

⁶Of the 52 groups that we contacted to obtain views on the energy-efficient and low-carbon technologies in the study, 31 provided their views on the study. App. I provides the details of our scope and methodology, including our selection of these groups. App. II lists the groups.

period—from about 3 years to nearly 7 years. However, most of the representatives of the seven industries that used about 80 percent of the manufacturing energy consumed in the United States in 1994 indicated this assumption may be too optimistic given their current capital constraints, market conditions, and existing manufacturing processes. On the other hand, some groups believed that certain assumptions in the study appear reasonable. For example, the Legislative Director of the International District Energy Association said that the study is not only reasonable, but may underestimate the potential carbon savings that industry might realize by 2010 from new technologies, such as cogeneration power systems that use waste heat to supplement an industry's energy needs.

The study has been cited as one of many documents considered in formulating the administration's October 1997 climate change proposal. Additionally, according to the Department's Assistant Secretary for Energy Efficiency and Renewable Energy, the study was one of the documents considered in formulating the emission-reduction goals for the United States at the December 1997 Kyoto Conference.

Background

The study by five DOE national laboratories⁷ was prepared in response to a growing recognition that any national effort to reduce the growth of greenhouse gas emissions must consider ways of increasing energy productivity. According to DOE laboratory officials, project discussions began in the summer of 1996, a peer review committee was formed in November 1996, and official authorization and a budget of \$500,000 were provided in December 1996 to "analyze the impact of energy efficiency technology on energy demand growth in the United States." Requested by DOE's Office of Energy Efficiency and Renewable Energy, the five-lab study had a central goal of quantifying the potential for energy-efficient and low-carbon technologies to reduce carbon emissions in the United States by 2010 for four sectors of the U.S. economy—buildings, industry, transportation, and electricity production. The building sector includes residential and commercial buildings, where energy is used for heating and cooling, lighting, refrigeration, cooking, heating water, and operating electrical appliances. The industrial sector includes all manufacturing, as well as agriculture, mining, and construction activities. The transportation sector includes passenger cars and light-duty trucks, freight trucks, railroads, aircraft, and marine vessels. The electricity-producing sector

⁷Argonne National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory.

includes electric power produced from coal, oil, natural gas, nuclear energy, hydroelectric systems, wind, solar energy, and biomass.

Initially, the study's focus was on energy efficiency from technology and the carbon savings that may accrue from such technologies. Subsequently, DOE laboratory officials said that the study's objectives were expanded about March 1997 to include not only the potential for carbon savings from energy efficiency, but also carbon savings from switching fuel supply options for electric power generation, such as from coal to natural gas. Because it was recognized that few low-carbon technologies would be implemented by the electricity sector without some type of external incentive or regulation, the officials told us that the study's objectives were also expanded to include an assessment of the impact of increasing the price of carbon-based fuels by \$25 and \$50 per ton.⁸ The officials noted that it is not unusual for a study to evolve over time and that the expansion of the study's objectives was in large part due to early comments from peer reviewers.

In calculating the carbon savings that could be achieved for each of the four sectors of the U.S. economy, the study uses three different, increasingly more aggressive, scenarios: (1) an efficiency scenario that assumes the United States takes an active role in public and private efforts to promote energy efficiency through enhanced research and development and market transformation activities; (2) a high-efficiency/low-carbon scenario that assumes a more aggressive national commitment to energy efficiency coupled with a \$25 per ton carbon fee; and (3) a high-efficiency/low-carbon scenario that, in addition to the aggressive national commitment to energy efficiency, assumes a \$50 per ton carbon fee. As shown in table 1, the study's estimate of carbon savings for the most aggressive scenario is more than 200 percent greater than its estimate for the first scenario.

⁸According to the study, a \$50 per ton increase in the price of carbon-based fuels would increase the price of a gallon of gasoline by 12.5 cents, increase the price of electricity produced from natural gas (at 53-percent efficiency) by 0.5 cents per kilowatt-hour, and increase the price of electricity produced from coal (at 34-percent efficiency) by 1.3 cents per kilowatt-hour.

Table 1: Potential Carbon Savings by 2010 Under the Five-Lab Study's Three Scenarios

Metric tons in millions				
Economic sector	First scenario	Second scenario	Third scenario	Percent increase ^a
Buildings	25	44	62	148
Industry	28	54	93	232
Transportation	73	88	103	41
Electricity production	b	48	136	b
Total	126	234	394	213

^aCompares savings under the third scenario with those under the first scenario.

^bUnlike the second and third scenarios, the first scenario assumes no carbon savings from fuel switching among utilities to reduce carbon in the production of electricity, such as converting from coal-fired to natural gas-fired power plants.

It is important to note that, at numerous points, the five-lab study qualifies its 2010 estimates by noting, among other things, that the calculations generally represent an “optimistic but feasible potential” for carbon savings. In some cases, particularly transportation, major breakthroughs in technologies would be needed to achieve these savings.⁹ DOE laboratory officials noted that, with the exception of the transportation sector, they believe the majority of the study’s 394 million metric tons of emissions reductions come from technologies that exist now or are near the end of their development phase. For example, the officials said that the 62 million metric tons of carbon emissions reductions estimated for the building sector can be achieved solely from technologies that exist today. Additionally, the officials emphasized that the study was not a projection of what would happen by 2010 but of what could happen if the nation embarked on a path to reduce carbon emissions that included aggressive federal policies and programs, strengthened state programs, and very active private sector involvement, beginning in 2000 and being progressively phased in by 2010.

Limitations of the Study

The five-lab study is an important step in evaluating the role that energy-efficient and low-carbon technologies can play in the nation’s efforts to reduce global warming gases, according to several groups that we contacted; however, the study’s scope and methodology may limit its

⁹By 2010, scenarios 1 and 2 would achieve only about 32 and 60 percent, respectively, of the 394 million metric tons achieved by the study’s most aggressive scenario; unless otherwise specified, assumptions relate to the scenario described as an aggressive national commitment to energy-efficient and low-carbon technologies coupled with a \$50 per ton carbon fee.

usefulness. For example, the study does not identify the type of policies that would be needed to get consumers and businesses to reduce carbon emissions by 394 million metric tons by 2010, and it does not indicate how these policies would be implemented. Additionally, the study does not address the broader economic effects on the nation's economy, such as how the \$50 per ton carbon fee may affect energy prices, energy consumption; and, eventually, economic activity and employment levels in the rest of the economy.

Unspecified Policies

The study bases its results on a package of unspecified policies that could bring about substantial increases in public and private research and development, acceleration of the adoption and use of energy-efficient technologies, advancement of the timing of postulated technological breakthroughs, and changes in the historical patterns of consumer and industry behavior. However, the study provides few suggestions as to what these policies would be, how they would be designed and implemented, or how they could be paid for. For example, a policy involving tax credits as an incentive for consumers to make energy-efficient purchases could have different economic and budgetary impacts from a policy involving regulations and standards, such as requiring manufacturers to meet minimum energy-efficiency levels for appliances. In its August 1997 peer review comments to DOE, the Treasury Department wrote that the five-lab study does not

"shed much light on what government can or should do to enhance the role technology will play in mitigating the growth of carbon emissions. In particular, the contribution of the report is to document energy savings and emissions reductions that would accrue if U.S. consumers and businesses move closer to the current (and, in some cases, reasonably anticipated) technology frontier. Despite its efforts to justify these moves as 'cost-effective,' the report does not address the policies that would be needed to actually get consumers and businesses to adopt the technologies described in the report, nor does it present a rigorous assessment of the societal costs that would accrue if they did."

In its August 1997 peer review comments to DOE, the Council of Economic Advisors was also critical of the study's failure to present the specific policies that would stimulate the adoption of these technologies. Similarly, according to an October 1997 study,¹⁰ the kinds of policies implemented to achieve any particular target for reducing greenhouse gas emissions "will have a significant impact on the costs." While acknowledging that the

¹⁰The Economics of Climate Change, S. DeCanio, Department of Economics, University of California at Santa Barbara (Oct. 1997).

types of policies chosen can have an impact, officials of DOE's Office of Energy Efficiency and Renewable Energy noted that, in their view, the main point of the October 1997 study is that there are many policies that could be implemented and have a low, if any, net cost.

DOE laboratory officials agreed that the study does not discuss the policies needed to achieve carbon savings by 2010 but explained that this was not a study objective or task from DOE. However, the officials also noted that there is fairly recent historic precedent for the types of behavior by consumers and industry modeled under the study's most aggressive scenario. For example, the officials said the growth in the demand for energy assumed under this scenario (0.13 percent annually through 2010) is more conservative than the actual growth in demand from 1973 through 1986 when the nation's economy grew by about 35 percent while primary energy demand remained unchanged. Additionally, the American Council for an Energy-Efficient Economy (ACEEE) indicated that the study's message is clearer because its focus on technology is unencumbered by policy discussions.

Other Economic Effects

The study does not address the various broader economic effects on the nation's economy. The study employed a methodology that, in essence, involved adding together the estimated net cost or savings to the economy for the adoption and use of each individual energy-efficient, carbon-reducing technology, with the savings based on the direct cost of adopting these technologies compared to the study's estimated energy savings over the life of these technologies.¹¹ However, this methodology focuses on one aspect of the economy—energy—and does not consider the broader impacts on other non-energy related aspects of the U.S. economy. Without considering the interrelationships between the changes that the five-lab study proposes—such as imposing a \$50 per ton carbon fee—and other sectors of the economy, the full effects of these changes are not known. For example, the study does not include any analysis of the impacts of a \$50 per ton carbon fee on energy consumption or economic activities elsewhere in the U.S. economy, including the impacts of these fees on energy prices and energy demand, as well as potential employment impacts. Several of the groups we contacted, such as the Global Climate Coalition and the International Project for Sustainable Energy Paths, believe the lack of an economic “feedback effect” in the study's methodology limits the usefulness of the study's results.

¹¹Direct cost includes the incremental cost of investment in the technologies as well as an allowance for the overall cost of a package of programs and policies required to achieve the carbon emissions reductions.

DOE laboratory officials recognized that the study does not address these broader economic feedback effects. In their opinion, these impacts would be minor because only one sector—electricity generation—relies primarily on the increased price of carbon as an economic stimulus to achieve significant carbon reductions. The officials noted that the study assumes that the estimated carbon reductions for two sectors—buildings and industry—rely primarily on more aggressive policies, and for another sector—transportation—the estimated carbon reductions rely on technological breakthroughs. Regarding increased prices for electricity generation, the officials envisioned that the overall net impact of the most aggressive scenario on the nation's economy would be small.¹² Additionally, the officials acknowledged that the study does not provide a quantitative analysis to support their view that the broader effects would be minor. Officials of DOE's Office of Energy Efficiency and Renewable Energy agreed that the full costs to the nation's economy are not considered in the study but emphasized that neither are the full range of benefits from energy-efficient technologies, such as the lower cost of state compliance with Clean Air Act regulations or the decreases in the costs for oil imports.

Disparities in Views About Key Assumptions

The study's calculations of carbon savings depend, in large measure, on the assumptions made about a host of factors in four sectors of the U.S. economy, including assumptions about consumers' purchasing behavior, loan rates, appliance standards, industrial capital constraints, the commercialization of near-term technologies, technological breakthroughs, future costs, and future benefits. Comments from interested and affected parties¹³ about the reasonableness of selected assumptions illustrated disparities in their views on some key assumptions, including those on discount rates, capital recovery factors, the rate of adoption of new technologies, the timing of technological breakthroughs, and the impact of changing the electricity-generating sector by 2010.

Discount Rates

The choice of a discount rate is a key assumption because it can affect whether an investment is viewed as cost-beneficial or not. In the five-lab study, the discount rate is used to value the stream of future benefits, such as estimated energy savings, accruing throughout the lifetime of an

¹²According to these officials, the impact of the most aggressive scenario would be less than 0.2 percent for the nation's approximately \$10 trillion gross domestic product by 2010.

¹³See footnote 6.

investment. Once these accumulated benefits have been calculated, they are used to determine the cost-effectiveness of a technology (energy savings less added investment cost). The study assumes that only cost-effective technologies will be adopted to achieve the level of carbon reductions estimated for each scenario. Assuming a higher discount rate will, among other things, cause fewer technologies to be viewed as cost-beneficial, whereas a lower discount rate means that more long-term investments with higher initial costs will be viewed as cost-beneficial. The study evaluates costs and benefits from two perspectives. The first, or more optimistic, case uses real discount rates¹⁴ of 7 percent for buildings, 10 percent for transportation, and 12.5 percent for industry. The second case uses higher discount rates—15 percent for buildings and 20 percent for transportation and industry, thus reducing the value of energy savings. According to DOE laboratory officials, the technologies included in the study are cost-effective even with the higher discount rates, and these rates are higher than those recommended by the Office of Management and Budget (OMB) for evaluating the costs and benefits of public policies.

The study's assumed discount rates for the transportation sector were not a significant issue among the groups we contacted; however, some groups were skeptical of the assumption of a 7-percent real discount rate for the building sector. For example, the Association of Home Appliance Manufacturers told us that the consumer discount rate for most replacement appliances, such as refrigerators, clothes washers, clothes dryers, and dishwashers, ranges from 12 to 15 percent. Similarly, officials from the Energy Information Administration (EIA)¹⁵ noted that consumers often charge such items on credit cards where the discount rate would range from about 12 to 16 percent, or more. Representatives of the Global Climate Coalition, National Association of Home Builders, and others also found the study's assumption of a 7 percent discount rate for the building sector too optimistic. Some noted, however, that the 7 percent would be reasonable for appliances included in new home purchases. EIA officials and others also noted that some replacement appliances—such as hot water heaters—are often purchased without regard to energy efficiency or cost-effectiveness. The officials explained that, although water heaters are a significant energy item in most homes, when water heaters fail, consumers rarely calculate a life cycle cost analysis, choosing instead to take what the plumber or local appliance store has most readily available.

¹⁴Real discount rates have been adjusted for inflation.

¹⁵EIA is an independent statistical and analytical agency that is required to prepare an annual report containing trends and projections in energy consumption and supply.

Representatives of other groups considered the 7-percent rate for the building sector reasonable and pointed out that rebates and low-interest financing, such as past utility-administered energy-efficiency programs, could lower the effective discount rate on building sector purchases to 7 percent. DOE laboratory officials explained that the 7-percent rate for the building sector would be consistent with a scenario in which the nation embarked on a path to reduce carbon emissions that included aggressive federal policies and programs. Additionally, the officials noted that the higher discount rates that some groups were more comfortable with are still within the range of discount rates that the study's most aggressive scenario concludes are still cost-effective.

Capital Recovery Factors for the Industrial Sector

A key assumption for the industrial sector involves the length of time expected for a capital investment to recover its costs—known as the payback period. The study assumes that, for investment planning purposes, industry can be persuaded to change the length of time expected for a capital investment to recover its costs for energy-efficiency investments from about 3 years to nearly 7 years.¹⁶ Under this scenario, the study assumes industry would install new energy-efficient technologies on twice as many operations as they would normally.

Most of the representatives of seven industries that used about 80 percent of the manufacturing energy consumed in the United States in 1994 indicated that the capital recovery factor assumed for the industrial sector may not realistically consider the capital constraints, market conditions, and existing manufacturing processes these industries operate under today. For example, in a November 1997 letter to the Secretary of Energy, the Chemical Manufacturers Association noted that the study's assumption that the industry could double the rate of capital stock turnover is "impossible or at a minimum, highly improbable." Representatives of the American Petroleum Institute explained that, in a business investment, (1) there is nothing special about energy-efficiency investments; (2) such investments have to compete directly with other investments for limited capital assets; and (3) the longer the payback period, the greater the risk and the uncertainty associated with an investment. Most of the representatives of the seven industries indicated that they would not be able to accept more than a 4-year payback; several said 3 years or less would remain their industry's normal payback period. Generally, the

¹⁶According to the study, the historical capital recovery factor (or payback period) for energy-efficiency investments by industry is about 33 percent (a 3-year payback); the study assumes that industry will change its capital recovery factor for energy-efficiency investments to 15 percent (nearly a 7-year payback).

representatives said that a 7-year payback is not realistic because of the higher risks and uncertainties associated with longer investments, the competing demands within their firms for investment capital, and their increasingly global competition.

On the other hand, the Director of ACEEE believed that industry could achieve this goal with little difficulty, and pointed out that this is consistent with the Council's 1997 report,¹⁷ which noted that industry often does not fully account for all the savings (both energy and nonenergy) in its financial analyses of such projects. DOE laboratory officials also believed that, given an aggressive package of federal policies promoting low-carbon technologies, along with federal research and development funds, industries would begin to look at such investments more favorably. They noted that for some larger investments—known as strategic investments—industry has been willing in the past to look at payback over a longer period of time. This is consistent, they noted, with a 1986 study¹⁸ which found that the capital budgeting practices of 12 large manufacturers varied based on the size of the project, with large projects having capital recovery rates ranging from 15 to 25 percent (paybacks ranging from about 7 to 4 years, respectively), and small- and medium-sized projects having capital recovery rates ranging from 35 to 60 percent (paybacks ranging from about 3 to less than 2 years, respectively).¹⁹ Many energy-efficiency projects in the industrial sector would be viewed as large projects.

Technology Adoption Rate for the Building Sector

One of the study's key assumptions involves the choice of "penetration rates," or the rates of adoption and use of energy-efficient technologies within a certain time frame. For the building sector, the study assumes a 65-percent penetration rate for its most aggressive scenario. This means that 65 percent of the energy savings achievable from maximum cost-effective energy-efficiency improvements are realized in residential and commercial buildings constructed or renovated from 2000 to 2010 and in the equipment subject to replacement during this time period.

¹⁷Energy Innovations: A Prosperous Path to a Clean Environment, Alliance to Save Energy, ACEEE, Natural Resources Defense Council, Tellus Institute, and Union of Concerned Scientists (June 1997).

¹⁸Capital Budgeting Practices of Twelve Large Manufacturers, M. Ross (Winter 1986).

¹⁹According to DOE, under the most aggressive scenario, investments in energy-efficient technologies would be on the lower end of the range (15 percent for large projects and 35 percent for small- and medium-sized projects).

Among the groups we contacted, we found a disparity of views on the reasonableness of the assumed 65-percent penetration rate. Several were skeptical of this level of penetration and questioned its reasonableness for some categories of new and retrofitted structures—such as low-cost, or entry-level, housing and rental properties. For example, the National Association of Home Builders told us that the entry-level housing market is extremely cost-sensitive and questioned whether builders of these structures would install the higher initial cost but more energy-efficient technologies described in the five-lab study. They were also skeptical that such homes would be equipped with higher initial cost, but more energy-efficient appliances. Similarly, the Air-Conditioning and Refrigeration Institute noted that the study's assumption of a 65-percent penetration rate is unrealistic, noting that generally "the people making the purchasing decision of air conditioning equipment are usually not the ones who will be paying the energy bills, so first cost becomes more important than operating cost."

Conversely, officials from the Alliance to Save Energy and ACEEE said that, in their view, the study's assumptions for the building sector are probably conservative. The officials said that, in the building sector, such things as aggressive national codes and standards over the home building industry and significantly higher energy-efficiency standards for appliance manufacturers could achieve the level of carbon emissions reductions estimated in the study. DOE laboratory officials noted that the 65-percent penetration rate was based on retrospective studies and their judgment of the percentage of cost-effective technologies that can reasonably be adopted over time with strong policy incentives. Additionally, the officials said that the 65-percent penetration rate for the building sector is conservative in their opinion because their analysis of this sector does not rely on any technological breakthroughs.

Timing of Technological Breakthroughs for the Industrial and Transportation Sectors

Some industry groups we talked with questioned the study's assumptions about the feasibility of some technologies being available by the 2010 time frame, noting that, in a few cases, the study's description of these technologies as "incremental" is incorrect because they still require fundamental breakthroughs. For example, according to officials of The Aluminum Association, the study's assumption that the aluminum industry will be able to use inert anode²⁰ technology to cost effectively smelt aluminum by 2010 is overly optimistic, with a more realistic time frame for

²⁰According to the February 1998 Inert Anode Roadmap, there are a number of barriers to the use of this technology, with some of the most critical barriers being the durability and longevity of the anode material, which fails to maintain the thermal and chemical properties needed.

implementing this breakthrough technology being 2020. To be cost-effective, the officials explained, anodes must last for 8 to 10 years, but anode life in ongoing experiments has ranged from a matter of hours to several weeks.

Similarly, some groups were skeptical that the breakthrough technologies envisioned for the transportation sector will be forthcoming soon enough to substantially reduce carbon emissions by 2010. According to representatives of the American Automobile Manufacturers Association (AAMA), the technology relied on for much of the carbon savings envisioned for light-duty vehicles is not expected to be available as quickly as the study assumes, and even if the technologies are demonstrated as viable, the benefits will probably not be realized until after 2010. For example, a substantial amount of the assumed reduction in light-duty vehicles' carbon emissions is expected to come from lean-burn engines that improve fuel economy but produce excessive amounts of nitrogen oxide, a Clean Air Act-regulated pollutant and an ozone precursor. According to AAMA officials, these engines still require significant technological development before they can be used in the U.S. market. They said that U.S. automotive manufacturers have been working on this type of engine for over 20 years, and—while it is technically feasible—it is still a question of technological cost-effectiveness today. They also pointed out that the median expected lifetimes of passenger cars and light-duty trucks—now about 14 and 16 years, respectively—are increasing, making it more difficult to achieve part of the carbon reductions estimated for the transportation sector by 2010. Officials of DOE's Office of Energy Efficiency and Renewable Energy noted that longer vehicle lifetimes will slow the pace of technological change but emphasized that the study scenarios consider these extended lifetimes.

The AAMA representatives and others pointed out that the study acknowledges that transportation sector reductions are not likely to materialize without a major change in U.S. policy to foster transportation modes that are more energy-efficient, as well as an intensification of research efforts. With respect to transportation sector technologies, the study cautions that

“because the outcomes postulated in the high-efficiency/low-carbon scenario require technological breakthroughs, they require a certain degree of luck to be achieved by 2010. There are no credible methods to accurately gauge the probability of such breakthroughs; we believe they stand a decent chance of occurring with an intensification of research

efforts, but we stop short of claiming that they are a likely outcome of such an intensification."

DOE laboratory officials acknowledged that, in some areas such as the transportation sector, technological breakthroughs will be needed but noted that it is plausible that additional funding for research and development activities could accelerate such breakthroughs. Additionally, officials of DOE's Office of Energy Efficiency and Renewable Energy noted that the study's most aggressive scenario does not anticipate that fuel cell vehicles will enter the market until 2007, yet, according to DOE, a number of manufacturers, including Daimler Benz, have announced that they plan to have such vehicles on the road before 2007. Also, according to DOE, Toyota has announced that it plans to introduce a hybrid vehicle in the U.S. market in 2000, several years ahead of the entry year assumed in the study's most aggressive scenario. Furthermore, officials from the American Forest and Paper Association said the assumptions about some breakthrough technologies for their industry, such as impulse drying, multiport cylinder drying, and on-machine sensors, are reasonable.

Changes in the Electricity Sector

Some groups believed the study's assumptions about changes that would occur in the electricity sector may be too optimistic. For example, the study's cost-benefit analysis assumes that a large segment of the electricity-generating sector can change from coal to natural gas without causing the price of natural gas to increase. However, officials from EIA, the American Petroleum Institute, and the Edison Electric Institute said that it is optimistic to assume that significant switching from coal to natural gas can occur without resulting in an increase in gas prices. DOE laboratory officials explained that this could happen due partly to the study's assumed reduction in overall energy demand for the building sector, after this sector adopts more energy-efficient technologies, such as highly efficient windows, doors, and appliances.²¹ One group questioned whether the assumed carbon savings would occur. A June 1998 American Petroleum Institute report²² asserts that a \$50 increase in the price of carbon-based fuels would not cause coal plants to convert to natural gas, and that—in order to achieve such conversions—the five-lab study further assumes that coal plants incur an additional environmental compliance cost of \$1,400 per ton for nitrogen oxides and \$100 per ton for sulfur

²¹By 2010, the study assumes that the building sector's energy demand decreases by about 5 percent, or about 2 quads, from 1997 levels, for the most aggressive scenario.

²²A Critique of the "Five Lab" Study, R. Sutherland, American Petroleum Institute (June 23, 1998).

dioxides.²³ DOE laboratory officials disagreed with this report and emphasized that the five-lab study's analysis of opportunities to convert coal plants to natural gas was based on a detailed plant-by-plant assessment of conversion costs.

Study's Role in Formulating Policy

In October 1997, the administration announced key elements of its proposal to reduce the emissions of greenhouse gases to the levels they were in 1990 by no later than 2012, with additional reductions below the 1990 levels in the ensuing 5-year period. Among other things, this proposal provided the framework for the level of greenhouse gas emissions reductions that the United States would commit to achieve in the next international negotiation to be held in December 1997 in Kyoto, Japan. Unlike the 1992 international climate change agreement that had called for voluntary reductions, the Kyoto conference was to establish binding commitments for reductions in greenhouse gases.

In the administration's October 1997 proposal, the five-lab study was cited as illustrating how greater use of many existing technologies could reduce carbon emissions. Also, the OMB Associate Director of Natural Resources, Energy and Science, told us that the administration relied on several key studies, including the five-lab study, in determining which activities should be a part of the administration's climate change initiatives. According to the five-lab study, the estimated amount of carbon that the United States would need to reduce in order to meet 1990 levels by 2010 is 390 million metric tons per year. The study found that, for its most aggressive scenario, the United States could reduce its emissions by 394 million metric tons by 2010 with a low to no net cost to the economy. According to the Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy, the five-lab study increased in its importance as support for the administration's climate change proposal when, in June 1997, a major study²⁴ dealing with the economic effects of global climate change policies could not be finalized.

In its December 1997 Kyoto Protocol negotiations, the United States agreed—subject to Senate ratification—to reduce the emissions of six

²³DOE officials pointed out that the study also analyzes the impact of lower costs of \$700 per ton for nitrogen oxides and no additional costs for sulfur dioxides. Using EIA's forecasted 2010 prices for coal and natural gas, however, shows that the incremental carbon reductions are less than one-third of the amount removed when the higher costs are assumed.

²⁴Draft report, Economic Effects of Global Climate Change Policies: Results of the Interagency Analytical Team (June 1997).

greenhouse gases²⁵ to 7 percent below 1990 levels.²⁶ However, one greenhouse gas—carbon dioxide—is by far the largest contributor to total U.S. greenhouse gas emissions, constituting more than 80 percent of total U.S. emissions in 1990 and projected to represent more than 80 percent in 2010. With its technological focus on the ability of the nation to significantly reduce carbon emissions, the five-lab study was also one of the key documents cited as support for the December 1997 Kyoto Protocol's emission-reduction commitments for the United States, according to DOE's Assistant Secretary for Energy Efficiency and Renewable Energy.

Agency Comments

We provided a draft of this report to the Department of Energy (DOE) for review and comment. The agency generally agreed with the overall message of the report, noting that it showed reasonable balance and was consistent with information DOE had received following publication of the five-lab study. DOE suggested several changes to clarify information in the report. For example, the agency suggested that we note in the section on other economic effects that, while the five-lab study did not consider the full range of costs to the nation, it also did not consider the full range of benefits of employing these energy-efficient and low carbon technologies, such as a lower cost of compliance with Clean Air Act regulations. We made this change and incorporated DOE's other comments where appropriate.

The agency expressed concern with the section on the study's limitations. While noting that the agency did not disagree with the two principal limitations presented in our report, DOE suggested that we state in that section that these limitations do not invalidate the conclusions of the five-lab study, most notably the study's essential conclusion that "a vigorous national commitment to develop and deploy energy efficient and low-carbon technologies has the potential to restrain the growth of U.S. energy consumption and carbon emissions . . . and can produce energy savings that are roughly equal to or exceed costs." We did not make this change, however, because the types of policies that might be needed to actually get consumers and businesses to adopt the technologies described in the report are not specified, and some have expressed concerns about the costs of these policies. For example, the Treasury

²⁵Carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

²⁶According to the Chair of the Council of Economic Advisors, after accounting for changes in the definition of the baseline for three of the six gases from 1990 to 1995 and the way that carbon sinks are figured, the actual reduction is no more than 2 to 3 percent more than the administration originally proposed as a negotiating position.

Department questioned the study's conclusion that carbon emissions can be reduced in ways that reduce energy costs more than they increase other societal costs, noting that in its view the study "substantially understates the costs of government policies to promote technology." Additionally, as noted in the section on key assumptions, the study's finding that a widespread adoption of energy-efficient technologies can be achieved with a low to no net cost to the nation is heavily dependent on the assumptions made, and we found a disparity of views on some of the key assumptions that may have influenced the study's results.

DOE also suggested that we include in our report that, since publication of the five-lab study, the administration has provided many of the elements of the policy roadmap in its announcement of a Climate Change Technology Initiative, which is a combination of higher budgets for technology research and tax incentives to accelerate the use of energy-efficient and low-carbon technologies. We did not include this in our report, however, since this initiative was outside the scope of our review. Also, in our April 1998 report Department of Energy: Proposed Budget in Support of the President's Climate Change Technology Initiative (GAO/RCED-98-147, Apr. 10, 1998), we raised several questions regarding DOE's proposed budget that the Congress may want DOE to address before the agency implements this initiative. Additionally, uncertainties regarding the lack of specific performance goals associated with this initiative were discussed in our June 1998 testimony Global Warming: Administration's Proposal in Support of the Kyoto Protocol (GAO/T-RCED-98-219, June 4, 1998).

DOE also questioned the relevancy of including comments from organizations that criticized some assumptions of the five-lab study as optimistic when compared to current conditions. We believe the viewpoints of these organizations are relevant and appropriately reflect their opinions of the reasonableness of certain key assumptions used in the study, taking into consideration current conditions and historical trends. Appendix III contains the full text of the agency's written comments and our responses.

We conducted our review from December 1997 through August 1998 in accordance with generally accepted government auditing standards. A detailed discussion of our scope and methodology is provided in appendix I.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 15 days after its date. At that time, we will send copies of the report to the Secretary of Energy and other interested parties. We will also make copies available to others upon request.

Please call me at (202) 512-6111 if you or your staff have any questions. Major contributors to this report are listed in appendix IV.

A handwritten signature in black ink, appearing to read "Peter F. Guerrero". The signature is fluid and cursive, with a large, stylized 'P' on the left and a more traditional 'Guerrero' on the right.

Peter F. Guerrero
Director, Environmental
Protection Issues

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Table 1: Potential Carbon Savings by 2010 Under the Five-Lab Study's Three Scenarios

Abbreviations

AAMA	American Automobile Manufacturers Association
ACEEE	American Council for an Energy-Efficient Economy
API	American Petroleum Institute
DOE	Department of Energy
EIA	Energy Information Administration
GAO	General Accounting Office
OMB	Office of Management and Budget

Objectives, Scope, and Methodology

In view of the Department of Energy's (DOE) five-lab study's potential influence on U.S. climate change policy,¹ Senators Larry Craig, Chuck Hagel, Jesse Helms, and Frank Murkowski asked us to provide information on (1) how the study's scope and methodology may limit its usefulness, (2) key assumptions that may have influenced the study's results, and (3) the study's role in the formulation of the October 1997 climate change proposal and the Kyoto Conference's emission-reduction goals for the United States.

To obtain information on the study's limitations and assumptions, we obtained and reviewed the final study, drafts of the study, and intramural and extramural peer reviewers' comments on drafts of the study. We also reviewed DOE's Energy Information Administration's (EIA) 1997 Annual Energy Outlook, which served as the principal basis for the estimated 2010 carbon emission levels under the five-lab study's business-as-usual case,² and we discussed various assumptions in the study with EIA officials associated with the development of the 1997 Annual Energy Outlook, as well as EIA's more recent 1998 Annual Energy Outlook. Additionally, we interviewed officials and obtained documents from Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, the two key laboratories in developing the study. We also contacted 52 organizations that we selected as being interested and affected parties, many with energy-efficiency expertise or able to offer informed opinions about the study's assumptions and limitations based on a particular field of expertise. In selecting these representatives, we contacted potentially interested and affected parties that were identified as being knowledgeable of the study, as well as energy-efficiency, industry, and environmental experts and other groups we identified from Internet searches, discussions with energy-efficiency experts, and our previous experiences. We selected organizations that represent different aspects of the four sectors of the U.S. economy discussed in the study—buildings, industry, transportation, and electricity production—as well as environmental groups. Not all of the representatives we contacted had read the study or wanted to express their views on it. Others had read and analyzed only those parts of the study that related to their sector, and they limited their comments accordingly. Of the 52 groups contacted, 31 commented on one or more aspects of the study. A list of the groups

¹Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond (Sept. 22, 1997).

²The study bases its savings estimates on the amount of carbon that would be emitted in 2010 if the nation continued on its current energy consumption and production path. This approach is generally known as the business-as-usual scenario.

commenting appears in appendix II. Additionally, while we discussed some aspects of the assumptions associated with the engineering-economic modeling approach used in some parts of the study, we did not attempt to verify the adequacy of these models or the alterations made to them for analyzing various study scenarios, such as the alterations of EIA's National Energy Modeling System model.

To describe the extent to which the final report's results were reflected in the October 1997 climate change proposal and the December 1997 Kyoto Conference's greenhouse gases emission-reduction goals for the United States, we relied on interviews, memorandums, press, and other briefings by the administration that cited the study as partial support for these proposals, the proposal and conference documents themselves, and testimony before the U.S. Senate. We conducted our review from December 1997 through August 1998 in accordance with generally accepted government auditing standards.

List of Nonfederal Groups Commenting on the Five-Lab Study

Air-Conditioning and Refrigeration Institute
Alliance to Save Energy
American Automobile Manufacturers Association
American Council for Capital Formation
American Council for an Energy-Efficient Economy
American Forest and Paper Association
American Foundrymen's Society
American Iron and Steel Institute
American Metalcasters Consortium
American Petroleum Institute
Association of Home Appliance Manufacturers
Chemical Manufacturers Association
Consumer Energy Council of America/Research Foundation
Edison Electric Institute
Environmental and Energy Study Institute
Global Climate Coalition
International District Energy Association
International Project for Sustainable Energy Paths
National Association of Home Builders
National Association of Manufacturers
National Hydropower Association
National Mining Association
Natural Gas Supply Association
Natural Resources Defense Council
Nuclear Energy Institute
Primary Glass Manufacturers Council
Reason Public Policy Institute
Renewable Fuels Association
Resources For the Future
Steel Founders Society of America
The Aluminum Association

Comments From the Department of Energy

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

Now on pp. 2 and 3.

 **Department of Energy**
Washington, DC 20585

July 27, 1998

Mr. Peter F. Guerrero, Director
Environmental Protection Issues
United States General Accounting Office
Washington, DC 20548

Dear Mr. Guerrero:

Climate Change: Information on Limitations and Assumptions of DOE's 5-Lab Study
(GAO/RCED-98-239, Code 160422)

Thank you for the opportunity to comment on the draft report, "Climate Change: Information on Limitations and Assumptions of DOE's 5-Lab Study." For the most part, the report shows reasonable balance in its overall conclusions. Throughout the report, a diversity of views is noted: on the one hand, some organizations found the 5 Lab study's assumptions to be too optimistic while on the other hand, some organizations felt that the 5-lab study underestimated the potential for carbon savings (pp. 3-4 and elsewhere). This is consistent with views expressed by various organizations in press releases and newsletter articles following publication of the report.

DOE does not disagree per se with the two principal limitations noted in the "Results in Brief" that "the study's usefulness is limited because it did not identify the policies needed to achieve its estimate of 394 million metric tons of carbon reductions by 2010" and that it "did not fully consider the costs to the nation's economy of reaching this goal." (pp. 2-3). Both of these limitations are noted in the 5-Lab Report. However, while these may be "limitations" of the study, the GAO report should state in the Results in Brief section that these "limitations" certainly do not invalidate the conclusions of the study. In fact, the GAO should clearly acknowledge in this section that the essential conclusion of the report, that "a vigorous national commitment to develop and deploy energy efficient and low-carbon technologies has the potential to restrain the growth of U.S. energy consumption and carbon emissions...and can produce energy savings that are roughly equal to or exceed costs" (5 Lab Study Executive Summary). What is at issue is the nature of the policies needed and the total macroeconomic costs of the reductions - not the basic conclusions of the study.

With regard to the nature of the policies, the GAO report repeatedly criticizes the 5 Lab Study for not specifying the precise policies needed to achieve the three carbon reduction scenarios. That fact is indeed a limitation and certainly worth noting. However, as stated clearly in the study, the purpose of the study was to assess the feasibility of major carbon emissions reductions through aggressive technology scenarios. The absence of a roadmap of specific policies does not in any way invalidate the conclusions of the study - especially since the study did consider a wide range of policy implementation costs in the calculation of overall costs and benefits (5 Lab Study pp. 1-11 to 1-15 and Appendix A-2). It should also be noted that since the publication of the study, the Administration has indeed provided many of the elements of the policy roadmap in the announcement of the Climate Change Technology Initiative - a combination of higher budgets for

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technology RD&D and tax incentives to accelerate the use of highly efficient and low-carbon technologies. This initiative, if enacted, will provide many of the actions and incentives to accelerate the use of energy efficient and low-carbon technologies that indeed can reduce carbon emissions at low cost.

With regard to the full costs to the nation's economy not being considered, the study acknowledges that a full macroeconomic analysis was not performed. However, the GAO report should also acknowledge that the study did also not consider the full range of benefits of these technologies. In particular, the scenarios would produce such benefits as lower cost of state compliance with Clean Air Act regulations, decreases in oil import costs (and hence less negative U.S. balance of trade), increased electricity system reliability (and therefore decreased costs of power outages) and possible increased public health due to concomitant reductions in emissions of NOx, sulfur, particulates and ozone. While it is quite difficult to quantify these benefits, many studies have suggested that the benefits are real and substantial.

Now on p. 13.

Several times in the GAO report, organizations appear to criticize the 5-Lab Report for not reflecting current conditions (e.g., top of p. 17). In particular, assumptions on discount rates, capital recovery factors and technology penetration rates are cited as optimistic given current conditions. DOE does not believe these comments are relevant. The point of the entire 5 Lab Study is to describe what could happen under conditions which deviate from today's situation -- i.e., where there's an aggressive national commitment to energy efficiency, including a \$50 per ton carbon fee. So by design the assumptions differ from a business as usual view of the future. These assumptions are well grounded in historical experience of what is indeed possible and the study states in several places that achieving these scenarios will be challenging, but is possible with a sustained national commitment.

The following more specific comments are offered.

- The major point of the DeCanio study is not that "the kinds of policies implemented to achieve any particular greenhouse gas emission reduction target "will have a significant impact on the costs" (p. 8). His main point is that there are many policies that could have very low, if any, net costs. The DeCanio article supports this position through illustrations and by citing the Economists' Statement on Climate Change that "For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve U.S. productivity in the longer run." These additional points should be noted.
- Change "transportation and industry" to "transportation" on p. 11. Some organizations did express disagreement with the discount rates used for industry, as described in the subsequent section on capital recovery rates.

Now on p. 6.
See comment 1.

Now on p. 9.
See comment 1.

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Now on p. 8.
See comment 1.

Now on p. 11.
See comment 4.

Now on p. 12.
See comment 5.

Now on p. 11.
See comment 6.

Now on p. 13.
See comment 7.

Now on p. 14.
See comment 8.

Now on p. 14.
See comment 9.

- Change "more than" to "approximately" in footnote 13, p. 10
- Insert the following material after the first sentence in the section on "Technology adoption rate" on page 14: "The study's adoption rate for the transportation sector was not a significant issue among the groups we contacted." DOE assumes this is the case since adoption rates for transportation are not discussed in the GAO report and because the 5-lab study is quite conservative in this regard.
- Eliminate the following phrase at the top of p. 15: "and questioned whether builders of these structures would install the most energy efficient technologies available." The 5-Lab Study does not assume that the most energy efficient technologies will be installed. Therefore this comment is irrelevant.
- At the top of p. 14 the GAO report fails to note that Marc Ross identified the lower discount rates as applicable to "strategic" investments--i.e., 15% for large projects (not 15 to 25%) and 35% for small to medium projects (not 35 to 60%). DOE believes this should be noted by GAO since the 5-Lab Study characterized its most aggressive scenario as one where energy investments are viewed as strategic
- At the bottom of p. 16, the AAMA suggests that the longevity of passenger cars and light duty trucks is increasing (now about 14 and 16 years, respectively), "making it more difficult to achieve part of the carbon reductions estimated for the transportation sector by 2010." But the 5-Lab Study's analysis explicitly uses the lifetime of vehicles as a parameter in the NEMS model--the longer the lifetime (as is the trend), the slower the pace of technological change. Therefore, how could the extended lifetime of vehicles make the carbon reductions more difficult to achieve? The scenarios are based on these extended lifetimes.
- Eliminate the following sentence from the bottom of page 17: "However, officials from EIA, the American Petroleum Institute, and the Edison Electric Institute said that it is optimistic to assume that significant switching from coal to natural gas could occur without an increase in gas prices." The sentence is not correct (i.e., higher gas prices would discourage shifts from coal to gas) and it is placed between two sentences that to belong together.
- Please insert the following sentence at the bottom of the section on "Timing of Technology Breakthrough" on page 17: "For example, they note that the study does not anticipate vehicles with fuel cells entering the market before 2007 in the most aggressive case, yet a number of manufacturers, including Daimler Benz, have announced that they will have such vehicles on the road before then." In addition, Toyota has announced it will introduce its Prius hybrid vehicle in the U.S. in 2000, several years ahead of the entry year described in the 5-Lab Study's most aggressive scenario."

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Now on p. 15.
See comment 10.

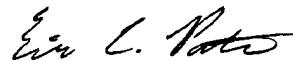
- Change the sentence above "Study's Role in Formulating Policy" on p. 18 to read: "DOE laboratory officials disagreed with this report, and emphasized that the 5-Lab Study's analysis of opportunities to convert coal plants to natural gas combined cycle plants was based on a detailed plant-by-plant assessment of conversion costs." The API report was not based on such a detailed analysis.

Now on pp. 14 and 15.
See comment 11.

- Earlier in that same paragraph on p. 18, the GAO report notes only the high end of the externality values that were considered. The sentence should be changed to show the ranges of \$700 to \$1400 per ton for nitrogen oxides and 0 to \$100 per ton for sulfur dioxide.

We do hope you will revisit the areas indicated in your report and consider our viewpoint before proceeding with your final version. Thank you again for affording the DOE the opportunity to comment on your drafted report.

Yours truly,



Eric C. Petersen, Acting Director
Office of Budget, Planning and Customer Service
Office of Energy Efficiency and Renewable Energy

The following are GAO's comments on the Department of Energy's letter dated July 27, 1998.

GAO Comments

1. We agreed with this comment and have revised the report accordingly.
2. See comment 1.
3. See comment 1.
4. The statement suggested by DOE has not been included because this section of our report only addresses the building sector and because the adoption rate of new technologies for the transportation sector was questioned by officials of the American Automobile Manufacturers Association.
5. This sentence was clarified to note that, because the entry-level housing market is so cost-sensitive, the National Association of Homebuilders questioned whether builders of entry level housing would install the higher-initial-cost but more energy-efficient technologies described in the study.
6. The study in question does not use the term "strategic investments" to describe the capital budgeting practices of firms, as suggested by DOE. The study does indicate that the capital budgeting practices of firms varied based on the size of the project, with large projects having capital recovery rates ranging from 15 to 25 percent, medium-sized projects, from 25 to 40 percent, and small projects, from 35 to 60 percent. We have added a clarifying note that DOE's interpretation of the study in question is that, under the most aggressive scenario, investments in energy-efficient technologies would be on the lower end of the range (according to DOE, about 15 percent for large projects and 35 percent for small- and medium-sized projects).
7. DOE's views have been added to this section of the report.
8. Due to a typographical error in the draft sent to DOE, the words "resulting in" were omitted, which distorted the meaning of the sentence. We have revised the report accordingly.
9. The information suggested by DOE has been added to this section of the report.

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10. Although our draft report already noted that DOE laboratory officials disagreed with the American Petroleum Institute report, we added DOE's suggested language about the analyses supporting the five-lab study's assessment of conversion costs.
11. We agreed with this comment and have added a clarifying note to this section of our report.

Major Contributors to This Report

Resources, Community, and Economic Development Division

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